

AMENDMENTS TO THE SPECIFICATION

Please amend page 1, first line after the title, as follows:

This is a divisional of Serial No. 09/893,624, filed June 29, 2001, now U.S. 6,709,563.

Please the paragraph beginning at page 7, line 4 as follows:

The present invention also ~~provide~~ provides a plating apparatus comprising: a first plating section for plating a surface of a substrate having fine recesses formed in the surface thereof and covered with a barrier layer and/or a seed layer in a first-stage; a first plating liquid feed section for feeding a first liquid into a plating chamber in the first plating section; a second plating section for plating the surface of the substrate which has undergone the first-stage plating in a second-stage; a second plating liquid feed section for feeding a second plating liquid into a plating chamber in the second plating section; and a transport section for transporting the substrate from the first plating section to the second plating section, wherein the first plating liquid has a higher polarization than the second plating liquid.

Please amend the paragraph beginning at page 10, line 15 as follows:

FIGS. 23A through 23C are diagrams schematically showing the respective states of poor ~~electrodeposition~~ electrodeposition, seam void, and particulate void, as observed under SEM;

Please amend the paragraph beginning at page 11, line 6 as follows:

~~FIG.~~ FIGS. 32A and 32B are views showing another transporting device, and FIG. 31A is a plan view and FIG. 31B is a side sectional view;

Please amend the paragraph beginning at page 11, line 24 as follows:

~~FIG.~~ FIGS. 40A and 40B are cross-sectional views illustrating the state of a seed layer and a void which has been formed according to a conventional method;

Please amend the paragraph beginning at page 20, line 4 as follows:

With this construction, as shown in FIG. 6, maintenance can be performed in such a state that the support 250 and the upper housing 264 are raised. A crystal of the plating liquid is likely to deposit on the inner circumferential surface of the weir member 58. However, the support 250 and the upper housing 264 are raised, a large amount of the plating liquid is flowed and overflows the weir member 58, and hence the crystal of the plating liquid is prevented from being deposited on the inner circumferential surface of the weir member 58. A cover 50b for preventing the splash of the plating liquid is integrally provided in the plating container 50 to cover a portion above the plating liquid which overflows during the plating process. By coating an ultra-water-repellent material such as HIREC (manufactured by NTT Advance Technology) on the inner surface of the cover 50b for preventing the splash of the plating liquid, the crystal of the plating liquid can be prevented from being deposited on the cover 50b.

Please amend the paragraph beginning at page 29, line 5 as follows:

FIG. 16 shows the details of each holding member 446. The holding member 446 is substantially columnar, and has near its top an engaging surface ~~444~~ 448 formed an annular groove form. The engaging surface ~~444~~ 448 is adapted to make a friction engagement with the periphery W' of the substrate W. The holding member 446 vertically penetrates a slot 450, which is formed in the peripheral portion of the rotatable member 444 and extends in the radial direction thereof, and is rotatable mounted at its lower part, which extends under the rotatable member 444, on a holding plate 452 that is located beneath the rotatable member 444 and is so constructed that it is allowed to rotate together with the rotatable member 444. The holding member 446 is held on the holding plate 452 in such a manner that it is allowed to rotatable about its own axis. Thus, the holding plate 452 has, mounted thereon, a small-diameter shaft 454 extending vertically upward, whereas in the inside of the holding member 446, a hole 456 is formed that extends upward from the bottom of the holding member 446. The hole 456 is moveable fitted with the small-diameter shaft 454, so that the holding member 446 can rotatable about the small-diameter shaft 454 as a center.

Please amend the paragraph beginning at page 31, line 4 as follows:

When the rotatable member 444 is driven to rotate and the holding member 446 revolves, a centrifugal force comes to act on the weight 458. The centrifugal force acting on the weight 458 is weak when the rotational speed of the rotatable member 444 is low, and so the weight 458 is kept motionless due to the pressure by the spring which forces the weight 458 in the home position. When the rotational speed of the rotational member 444 is higher than a particular value, the centrifugal force acting on the weight 458 exceeds the counter pressure of the spring and causes the weight 458 to swing, whereby the holding member 446 swings (rotates) about its own axis. Since the holding member 446 is in friction engagement with the periphery W' of the substrate W as described above, the swinging of the holding member 446 makes the substrate W rotate in the direction of arrow B shown in FIG. 17, thus shifting the engaging portion to the periphery W' of the substrate W.

Please amend the paragraph beginning at page 33, line 17 as follows:

A plating method of the present invention will now be described by referring to FIG. 19. According to this embodiment, of the four plating sections 22 as shown in FIG. 1, one is employed as a first plating section 22a for a first-stage plating and the other three are employed as second plating sections 22b for second-stage plating. The first-stage plating in the first plating section 22a is to reinforce the thin portion in the seed layer 7 as shown in FIG. 40A so as to obtain a uniform thickness of seed layer 7, and the second-stage plating in the second plating sections ~~226~~ 22b is to deposit copper onto the reinforced seed layer for filling with copper.

Please amend the paragraph beginning at page 33, line 28 as follows:

In the first plating section 22a, a plating liquid (first plating liquid) is used, as the plating liquid 45 (see FIG. 3), which contains divalent copper ions, a complexing agent and a pH adjusting agent, and does not contain any alkali metal nor any cyanide, and which has an excellent uniform electrodeposition property, e.g. a plating liquid consisting of copper pyrophosphate, pyrophosphoric acid and choline. The first plating liquid is maintained within a

pH range of 7-14, preferably at a pH of about 9, by the addition of the pH adjusting agent such as ~~etholin~~ choline. This avoids a case where the complex fails to effectively combine with copper and forms an incomplete complex when the pH is too low, or a case where a variant form of complex is formed to produce a sediment when the pH is too high. The pH adjusting agent is not always necessary. The divalent copper ions are produced by the dissolution of a copper salt such as copper pyrophosphate, copper sulfate, copper acetate, copper chloride, EDTA-Cu, copper carbonate, copper nitrate, or copper sulfamate.

Please amend the paragraph beginning at page 38, line 21 as follows:

A process of annealing a substrate W may be performed between the Step 7 and the Step 8. When a substrate W is annealed at 200-500°C, preferably about 400°C, the electric characteristics of copper film formed on the substrate W can be improved. For example, if the bevel-etching/chemical cleaning section 16 has a supplementary function of a cleaning and drying unit, then an annealing section (annealing unit) may be provided ~~inst ad~~ instead of ~~th~~ the cleaning/drying ~~s-ction~~ section 12.

Please amend the paragraph beginning at page 41, line 6 as follows:

Note: A: Copper pyrophosphate (g/L)

B: Pyrophosphoric aid (g/L)

C: Copper sulfate (g/L)

D: EDTA-4H (g/L)

E: ~~Etholin~~ Choline (ml/L)

F: Organic additive (ml/L)

Please amend the paragraph beginning at page 45, line 5 as follows:

Note: A: Copper pyrophosphate (g/L)

B: Pyrophosphoric acid (g/L)

C: ~~Etholin~~ Choline (ml/L)

D: TMAH (tetramethyl ammonium hydroxide) (ml/L)

E: Organic additive (ml/L)

Please amend the paragraph beginning at page 47, line 8 as follows:

In the semiconductor substrate W, as shown in FIG. 25A, an insulating film 102 comprising SiO₂ is deposited on a conductive layer 101a of a substrate 100 on which semiconductor devices are formed, a contact hole 103 and a trench ~~4~~ 104 for an interconnect are formed by lithography and etching technology, a barrier layer 105 comprising TiN or the like is formed thereon, and a seed layer 107 is further formed thereon. The seed layer 107 may be formed beforehand by sputtering, and a reinforcing seed layer for reinforcing the seed layer 107 may be formed thereon. As shown in FIG. 25B, copper plating is applied onto the surface of the semiconductor substrate W to fill copper into the contact hole 103 and the trench 104 of the semiconductor substrate W and deposit a copper film 106 on the insulating film 102. Thereafter, the copper film 106 on the insulating film 102 is removed by chemical mechanical polishing (CMP) to make the surface of the copper film 106, filled into the contact hole 103 and the trench 104 for an interconnect, flush with the surface of the insulating film 102, as shown in FIG. 25C. An interconnect protective film 108 is formed on the exposed metal surface.

Please amend the paragraph beginning at page 50, line 6 as follows:

Then, the semiconductor substrate W itself is directly heated by the lamp heaters 317 to render the temperature of the semiconductor substrate W, for example, 70°C (maintained until termination of plating). Then, the plating liquid heated, for example, to 50°C is ejected from the shower head 341 to pour the plating liquid over substantially the entire surface of the semiconductor substrate W. Since the surface of the semiconductor substrate W is surrounded by the ~~dame~~ dam member 331, the poured plating liquid is all held on the surface of the semiconductor substrate W. The amount of the supplied plating liquid may be a small amount which will become a 1 mm thickness (about 30 ml) on the surface of the semiconductor substrate W. The depth of the plating liquid held on the surface to be plated may be 10 mm or less, and may be even 1 mm as in this embodiment. If a small amount of the supplied plating liquid is

sufficient as described above, the heating apparatus for heating the plating liquid may be of a small size. In this embodiment, the temperature of the semiconductor substrate W is raised to 70°C, and the temperature of the plating liquid is raised to 50°C by heating. Thus, the surface, to be plated, of the semiconductor substrate W becomes, for example, 60°C, and hence a temperature optimal for a plating reaction can be achieved. If the semiconductor substrate W itself is adapted to be heated as described above, the temperature of the plating liquid requiring a great electric power consumption for heating need not be raised so high. This is preferred, because the electric power consumption can be decreased, and a change in the property of the plating liquid can be prevented. The electric power consumption for heating of the semiconductor substrate W itself may be small, and the amount of the plating liquid stored on the semiconductor substrate W is also small. Thus, heat retention of the semiconductor substrate W by the lamp heaters 317 can be performed easily, and the capacity of the lamp heaters 317 may be small, and the apparatus can be made compact. If means for directly cooling the semiconductor substrate W itself is used, switching between heating and cooling may be performed during plating to change the plating conditions. Since the plating liquid held on the semiconductor substrate is in a small amount, temperature control can be performed with good sensitivity.

Please amend the paragraph beginning at page 52, line 20 as follows:

The plating liquid once used is not reused, but thrown away. As described above, the amount of the plating liquid used in this apparatus can be made very small, compared with that in the prior art. Thus, the amount of the plating liquid which is discarded is small, even without reuse. In some cases, the plating liquid recovery nozzle 365 (not shown) may not be installed, and the plating liquid which has been used may be recovered as a plating waste liquid into the recovery vessel 361, together with the cleaning liquid.

Please amend the paragraph beginning at page 57, line 7 as follows:

As shown in FIGS. 31A and 31B, four film thickness sensors directly attached, in a buried state, to the robot hand 540. Any film thickness sensor S may be used, if it can measure the film

thickness. Preferably, an eddy current sensor is used. The eddy current sensor generates eddy currents, and detects the frequencies or losses of electric currents which have passed through the substrate W and returned, thereby measuring the film thickness. The eddy current sensor is used in a non-contact manner. An optical sensor is also preferred as the film thickness sensor S. The optical sensor irradiates a sample with light, and can directly measure film thickness based on information on reflected light. The optical sensor is capable of measuring film thickness of not only a metal film, but also an insulating film such as an oxide film. The positions of installation of the film thickness sensors S are not limited to the illustrated positions, and the film thickness sensor S is attached in an arbitrary number at a location where measurement is to be made. The robot hand 540 is available as a dry hand handling a dry substrate W, or as a wet hand handling a wet substrate W. The film thickness sensor S can be attached to either hand. When the transporting device 514a (514b) is used in a plating section, however, there is need to measure the film thickness of the substrate W in such a state that 57 only the seed layer is initially provided. Thus, it is necessary to measure the film thickness of the substrate W, initially in a dry state, which is placed in the substrate cassettes ~~510~~ 531, ~~510~~ 531 (see FIG. 27). Hence, it is desirable to attach the film thickness sensor S to the dry hand.